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BOOK OF ABSTRACTS

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CONTENTS

Transition Models for Turbomachinery Boundary Layer Flows

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Keywords: turbomachinery flows, transition models, Reynolds-averaged Navier-Stokes equations, intermittency, laminar fluctuation kinetic energy

1. Summary

First, the mechanisms of laminar-turbulent transition, relevant for turbomachinery flows, are briefly discussed. Special attention is given to the effect of impacting wakes by upstream blade rows in relative motion. Then, the ways of expressing the processes by transition model ingredients connected to RANS turbulence models are explained. Models are classified in one way as models using intermittency and models using fluctuation kinetic energy. A second classification is by the categories of correlation-based models and sensor-based models. The intermittency is the fraction of time that the flow is turbulent in a position in the boundary layer during transition. It is a parameter that evolves from zero in a fully laminar flow to unity in fully turbulent flow. In two-equation turbulence models, it is used either as multiplier of the eddy viscosity or as multiplier of the production term in the equation of turbulent kinetic energy. Models using this concept may rely on algebraic description of intermittency along the boundary layer, or across the boundary layer, or intermittency derived from a dynamic transport equation. Intermittency can be derived from correlations, involving boundary layer parameters, in particular the boundary layer momentum thickness, but models using these correlations do not necessary calculate these parameters directly. They may be derived from relevant sensor parameters that, on their turn may be described algebraically or by a dynamic transport equation. The objective is to reach a model that is local, which means that it does not require operations that cross grid partitioning borders in a parallel calculation organisation. The laminar fluctuation kinetic energy is the kinetic energy of non-turbulent fluctuations prior to transition. In models of this type, this kinetic energy is derived from a dynamic transport equation and transition is simulated by transfer to turbulent fluctuation kinetic energy. The transfer may be derived from correlations, but usually it is activated by sensor parameters. Sensor parameters are dimensionless quantities that characterise features of the transition process. In the presentation, we discuss some models of each of the categories.

2. Results

We test relevant models for wake-induced transition by moving wakes impacting on the suction side of a turbine cascade. The figure shows the space-time diagrams of the boundary layer shape factor, obtained by the experiments [1], the local correlation-based intermittency transport model by Menter, Langtry et al., our own wall-normal algebraic intermittency model and the laminar fluctuation kinetic energy model by Walters and Cokljat [2]. In between wake impacts, the initially laminar boundary layer on the suction side becomes turbulent near the trailing edge. Under wake impact, the transition is much earlier. All models capture the earlier transition by wake impact, but there are quantitative differences. We discuss these in the presentation.

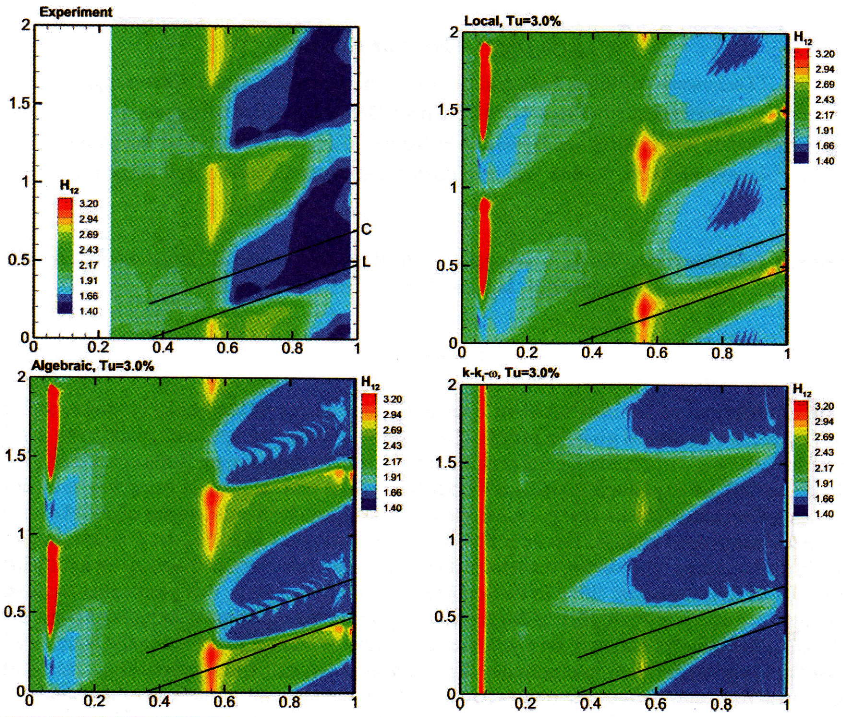

Figure. N3-60 cascade, bar diameter 6 mm, background turbulence level 3%. Space-time diagrams of shape factor: x: stream-wise position divided by chord, y: time divided by wake passing period. L and C: trajectories of leading edge and centre of moving wakes. Top left: experiment. Top right: local correlation-based dynamic intermittency model. Bottom left: wall-normal algebraic model. Bottom right: laminar fluctuation kinetic energy model.

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Index of Authors